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Building an Analysis Schedule – Lessons Learned from the SGSS Program

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Laurel, MD

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Abstract

Constructing a JCL model involves bringing together important program elements: Cost, risk, and schedule. The JCL model's core is the schedule; the linking of costs and risks to the schedule is what allows the implementation of time-dependent costs and, ultimately, an analysis that jointly considers cost and schedule. It follows, then, that one of the first, and often largest, difficulties in constructing a JCL model is the development of the schedule backbone.

Modern program master schedules (e.g., Integrated Master Schedules-IMS) are typically massive and labyrinthine. This presentation covers an approach for developing an analysis schedule which is directly informed by an IMS, but is not purely derived from summation of the activities. This highlights a key enable in that an analysis schedule does not need to be a rote summarization of the IMS. This presentation will cover the key attributes of an analysis schedule and how it can be constructed from high-level knowledge of program work flows and other available data.

Topics

- **SGSS Overview**
- **Analysis Schedule Methods**
  - Direct Use
  - Summarization/GEMS Analysis Schedule
  - Work-Flow Based
- **SGSS Analysis Schedule**
- **Lessons Learned**
- **Conclusions**

SGSS Program Overview

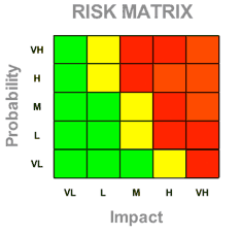
- The SGSS Project will develop and deliver a new ground system that will enable the Space Network (SN) to continue safe, reliable, and cost efficient operations for the next several decades
  - The SN, a designated national resource, provides essential communications and tracking services to NASA human exploration & scientific missions and non-NASA missions
  - The SN space segment will be replenished with three new spacecraft to be launched over the next five years
  - The current SN ground segment, developed in the mid 1990s, is based on obsolete technologies and becoming increasingly difficult to operate safely and reliably
- SGSS will allow the SN to support an evolving customer set by:
  - providing all of the capabilities and capacities required by current SN customer missions
  - expanding the capabilities and capacities of the SN to support new services for new customers in the near to mid term
  - delivering an extensible and expandable system to easily allow future modifications to implement services not yet defined
  - enabling drastic reductions in operations and maintenance costs

SGSS PDR Review – JCL Requirement

- **NPR 7120.5D (NID 7120-97) contains requirements and definitions of the Joint Confidence Level product relevant to SGSS:**
  - *Paragraph 2.4.3.2: At KDP 1/KDP C, these [tightly coupled, single-project, or estimated LCC over 250$M] programs or projects shall generate a cost-loaded schedule and a probability calculation that meet cost, schedule, and a JCL. The JCL is the probabilistic analysis of the coupled cost and/or schedule to measure the likelihood of completing all remaining work, including mitigating risks and conducting any operations prior to transition to Phase E, while meeting both cost and schedule simultaneously.*
  - Paragraph 2.4.4: *Mission Directorates shall plan and budget these programs and projects based on a 70 percent joint cost and schedule confidence level or as approved by the Decision Authority. Any JCL approved by the Decision Authority at less than 70 percent must be justified and documented.*
  - Paragraph 2.4.4.1: *Mission Directorates shall ensure funding for these programs and projects are consistent with the Management Agreement and in no case less than the equivalent of a 50 percent joint confidence level.*

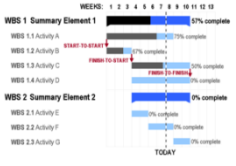
The High-Level Integrated Cost Schedule Modeling Process – Key is Analysis Schedule

Risk



Collect Risk Data → Assign Likelihood, Determine Impacts → Map to Sched Activities

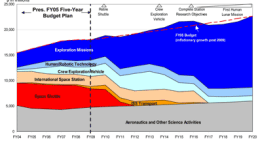
Sched



Collect Sched Related Data → Determine High-Level Flow → Generate Analysis Schedule → Update Analysis Schedule → Incorporate Uncertainty → Validate File → Run Analysis

Assess Durations → Incorporate Uncertainty

Cost



Collect Cost Data → Identify Cost Behavior (TD vs TI) → Map to Sched Activities → Assess Cost Uncertainty

time

The Need for an Analysis Schedule

- **Performing a joint cost and schedule risk analysis on a program requires creating a model of the schedule logic**
  - This model serves as the backbone for the analysis – cost, risks and uncertainty are linked into the logic to assess impacts
- **In general, project/program schedules are unsuitable for this role**
  - Size, complexity, detail, and other common logic issues (e.g., constraints)
- **The schedule that is used must be created for its role in the analysis using available data (including the program schedule)**
  - Typically referred to as an “analysis schedule”

Attributes of an Analysis Schedule

- √ **Displays major work-flows of a project**
- √ **Identifies work required to support major deliverable / tracking items**
- √ **Structured around management/ budget responsibility**
- √ **Allows linkage of budgeted work effort to schedule scope**
- √ **Enables alignment with cost/budget data**
- √ **Provides insight into major cross-dependencies within or across management responsibility boundaries**
- √ **Creates a solid framework for incorporating cost / schedule uncertainties and discrete risk events**
- √ **Has traceability and transparency to more detailed IMS and schedule products**
- √ **Does not focus on detailed step by step work items or on describing the specific detailed task flow for critical paths**

Program Schedules Normally Don't Make Good Analysis Schedules

- **A good program schedule will still have a number of issues impeding its use in an analysis**
  - Massive size - the most practical issue as the amount of logic alone will significantly slow simulation
  - Logic unnecessary for analysis – for example, multiple lower-level schedules may be linked together through a separate links section, and LOE tasks may be divided into quarterly blocks
  - Considerable detail – Beyond contributing to size, this causes great difficulty in assigning uncertainty
- **Program schedules can have other, more immediate problems as well**
  - Overuse and misuse of constraints – ASAP is most desirable, and SNET is often necessary, but most other uses of constraints can defeat the purpose of the simulation
  - Poorly-linked logic – often associated with too many constraints (used to force activities to certain dates when the natural logic fails), this issue can essentially break the analysis

Analysis Schedule Approaches

- **Three approaches**
  - Direct use of IMS
  - Summarization of IMS
  - Creation of a new schedule informed by IMS
- **The typical approach has been to start from a detailed IMS**
  - Remove items unnecessary to the cost analysis
  - Collapse isolated serial tasks
  - Organize into logical work flows
  - Add cost hammocks

Analysis Schedule Methods – Direct from IMS

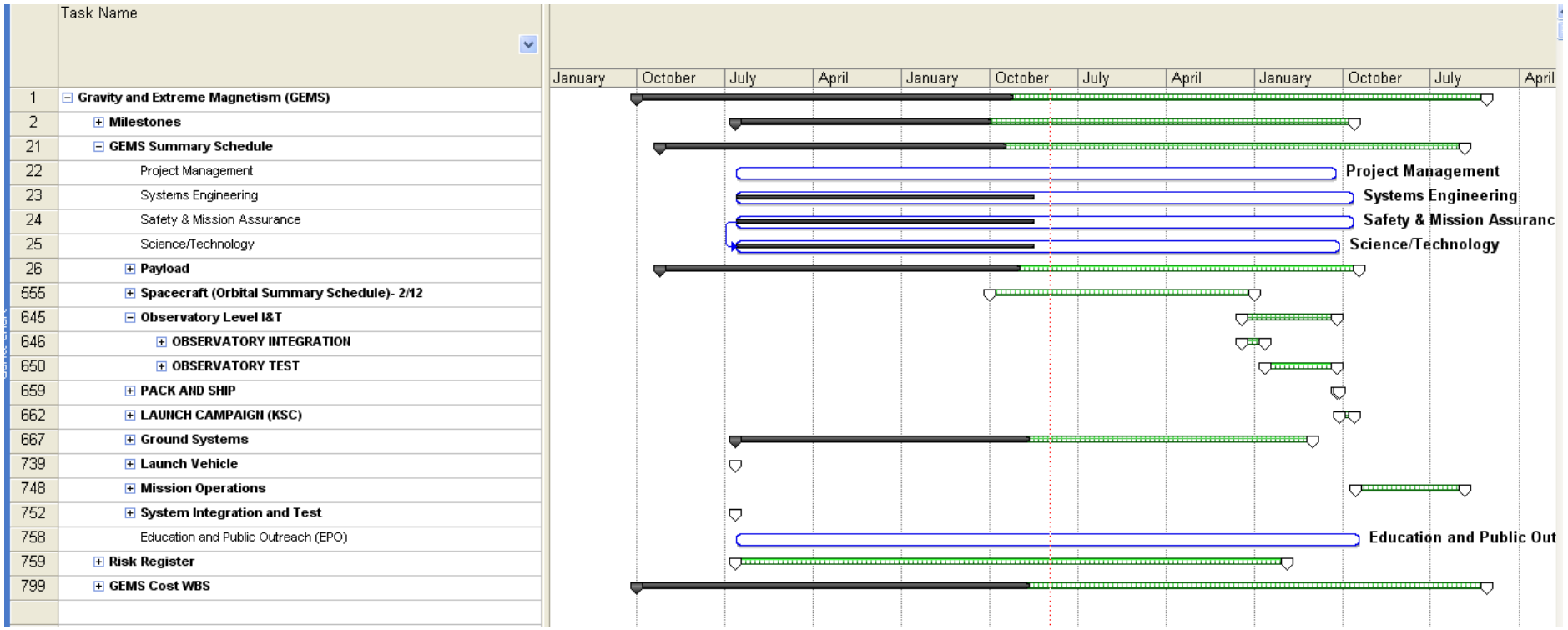
- **This approach simply avoids the process of creating an analysis schedule – may be suitable for a small, simple IMS**
- **Appealing because it:**
  - Avoids the effort associated with the analysis schedule (which can be a significant amount of the whole JCL process)
  - Allows direct updating when a new IMS becomes available
  - Costs and risks *may* be mapped with great fidelity
- **However,**
  - Size may make simulation impossible – Large portions of the IMS may not factor into the analysis, but removing those parts from the analysis basically starts the user down the summarization method path
  - IMS may not be healthy (constraints and logic) – correcting these issues in a large schedule can also be time-consuming
  - Difficult to summarize and report results meaningfully
  - Likely at too low a resolution to easily map costs and risks
  - Uncertainty will be very difficult to apply reasonably – Too difficult to allocate to lower levels, too difficult to perform analysis on every activity

Analysis Schedule Methods – IMS Summarization

- **Summarization of IMS:**
  - Process involves summarizing and rearranging the IMS
  - This approach has an intuitive appeal – if the IMS has too much detail, a large amount can be removed by simply combining tasks in series
  - In addition, tasks that are unnecessary for the analysis can be removed
- **The practical issues with this approach**
  - Labor-intensive – the process of simplifying an IMS in excess of 10000 lines can be prohibitively time-consuming
  - Although systematic, the purely algorithmic processes (collapsing serial activities in particular) causes issues when the schedule is updated and the summarization has to re-occur
- **Summarization IMS is a good option for healthy, smaller schedules with simpler logic – example: GEMS program**

Top-Level Summary Analysis Schedule GEMS

- **Summary Analysis Schedule has same top-level flow as the GEMS management schedule, but the detail is directly informed by IMS**



GEMS Analysis Schedule Format

- **Used special fields to allow tagging of file to provide linkage to source data (GEMS IMS)**

Task Name	Key Lir	Task Calen	Analysis Sched IMS ID	Analysis Sched - IM ID Finish	Anlys Sched - IMS Start Da	Anlys Sched - IMS Finish Date	Analysis Schedule - IM Duration	Duration
Polarimeter Assembly	**No**	**Holidays**	**535**		**Wed 12/10/08**	**Mon 2/25/13**	**1035 d**	**1035 d**
Mirrors	**No**	**None**			**Fri 10/1/10**	**Mon 12/3/12**	**0 d**	**768 d**
Mirror Requirement	No	Holidays	7545	12872	Fri 10/1/10	Tue 8/30/11	229 d	229 d
Foils	No	Holidays	9450	1461	Tue 2/15/11	Thu 5/10/12	302 d	302 d
Structures	**No**	**None**			**Tue 6/28/11**	**Fri 10/5/12**	**0 d**	**731 d**
Mirror Housings	**No**	**Holidays**	**9468**	**9468**	**Tue 6/28/11**	**Fri 10/5/12**	**312 d**	**125 d**
Mirror Alignme	**No**	**Holidays**	**12980**	**12980**	**Tue 6/28/11**	**Mon 8/20/12**	**279 d**	**243 d**
Connector Ring	**No**	**Holidays**	**13019**	**13019**	**Tue 6/28/11**	**Fri 5/11/12**	**210 d**	**210 d**
Thermal Shields	No	Holidays	12900	12889	Thu 12/15/11	Mon 10/1/12	191 d	191 d
Mirror Integration, T	**No**	**Holidays**	**12888**	**12888**	**Wed 4/25/12**	**Mon 12/3/12**	**152 d**	**757 d**

Identifies est. duration between dates

Identifies IMS reference dates for start and finish

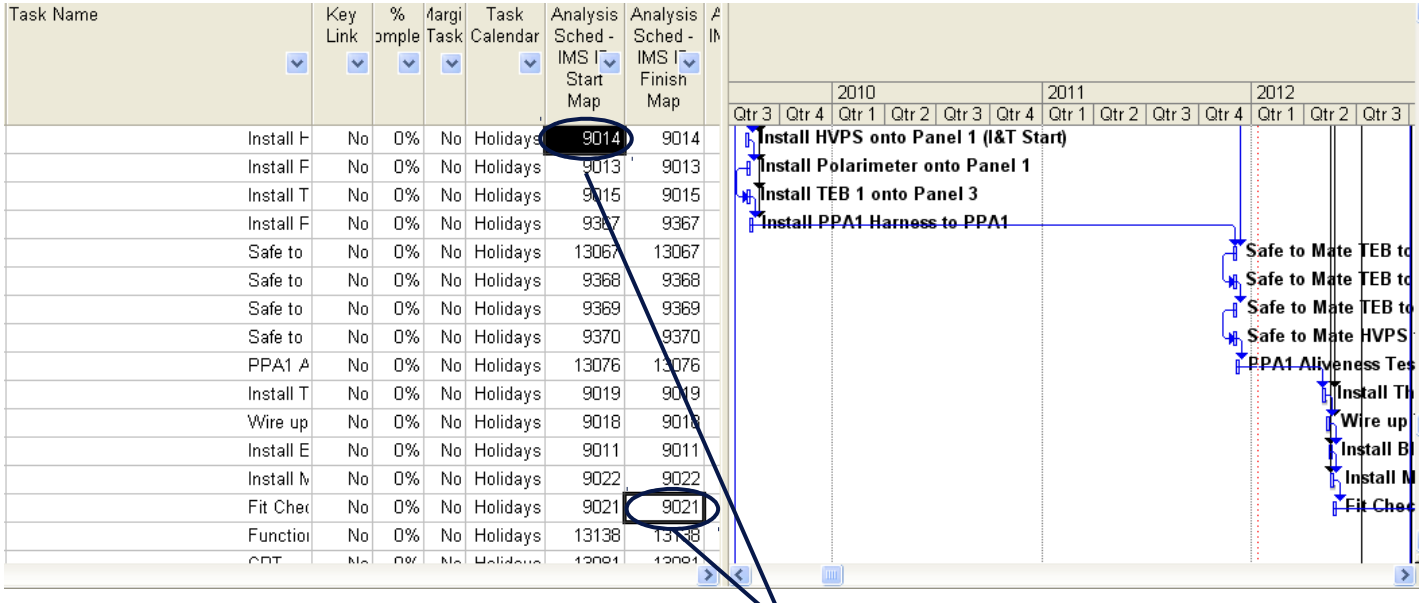
Identifies IMS finish task

Identifies IMS Start task

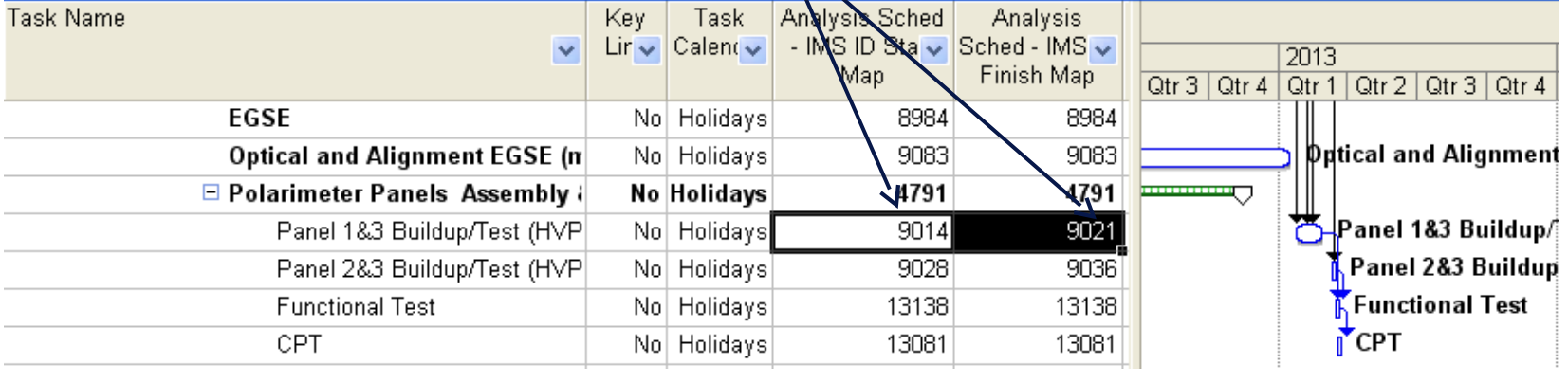
Identifies if it's a key link in schedule flow

IMS Summarization Process – Activities Collapsed in a Systematic Manner

- **First Order Schedule Minimization**



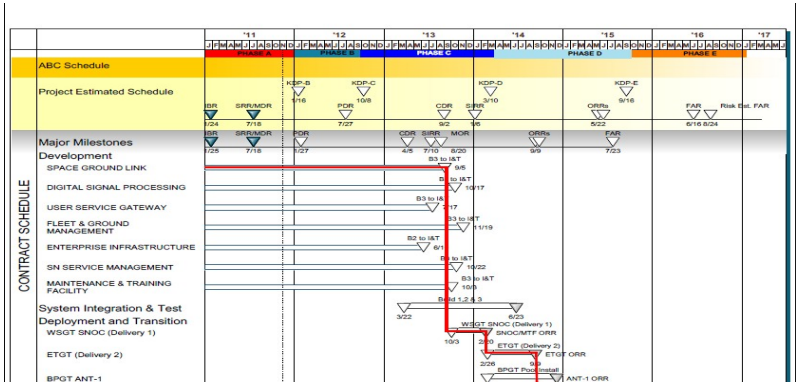
- **Schedule Summarization**



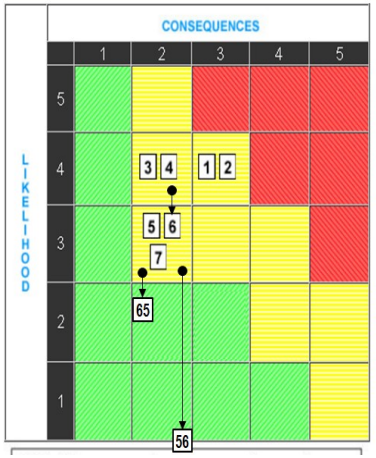
Analysis Schedule Methods – IMS Informed

- **Starting from a blank file and constructing the analysis schedule may sound more labor-intensive than the modification of an existing file, but is a great approach to develop a solid structure that can be easily updated**
- **Where to start?**
  - The analysis schedule will need to be based on the program work flow, which is often represented in presentations to management
  - Even a “cartoon” schedule in a presentation can provide a starting point
- **The key is to remember that the analysis schedule is a model first, and a schedule second**
  - The backbone of the analysis schedule is constructed from knowledge of the program work flow and other available information (existing risks, uncertainty information, level of cost mapping)
  - The IMS, then, can be used as a database of durations and, if adequately constructed, can provide insight into the logic that may be unclear

Data Relationships for Structuring Analysis Schedule Backbone

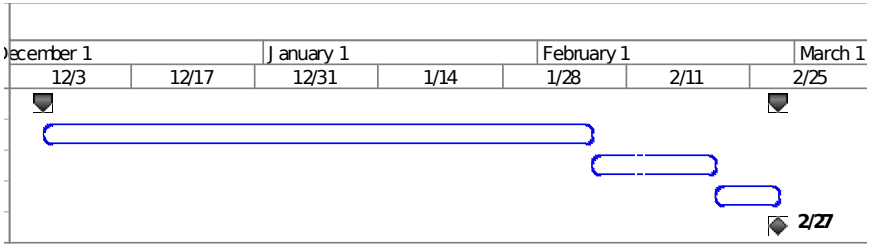


High-level contract and management schedules provide structural information



Cost structure and risk information provides insight on level of detail

9.03.04.07 USG User Service Simulation
9.03.04.07.01 USG User Service Simulation - Harris
9.03.04.09 USG Element I&T
9.03.04.09.01 USG Element I&T - Harris
9.03.05 FGM
9.03.05.01 FGM Element Leadership
9.03.05.01.00 FGM Element Leadership
9.03.05.02 FGM Element Level Engineering
9.03.05.02.00 FGM Element Level

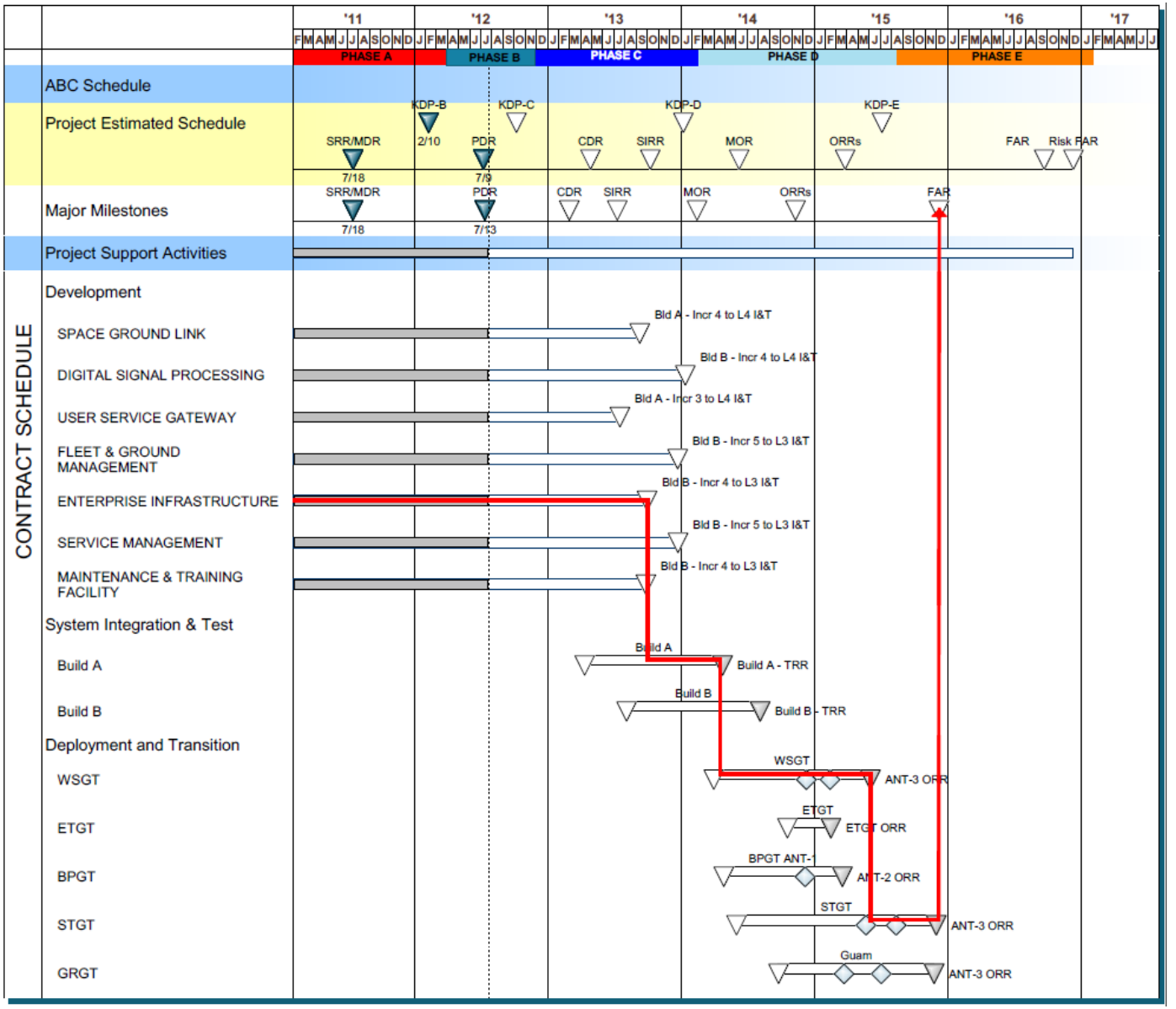


IMS provides information on logic and durations

IMS–Informed Analysis Schedule Details

- **Many programs are easily expressed at a high level, for example: Design and development, integration and test, and launch/deployment**
  - Start there, then answer the question – Why add more detail?
  - The answer should be for the mapping of risks and costs, and possibly uncertainty
  - At some point, adding detail will not help you assign risks or map costs, and continuing will only make application of uncertainty harder
- **With that in mind, the model may still be forced to a lower level of detail than desired because of logic**
  - Example: A testing activity that would preferably be a single line may have to be split into test-prep and test activities because test-prep activities are a predecessor to another important activity
  - Even with no particular risks or cost associated with test-prep, the additional line and logic may be preferable to ignoring the logical connection or attempting to “fake” it with a lag or lead

SGSS Schedule



SGSS IMS

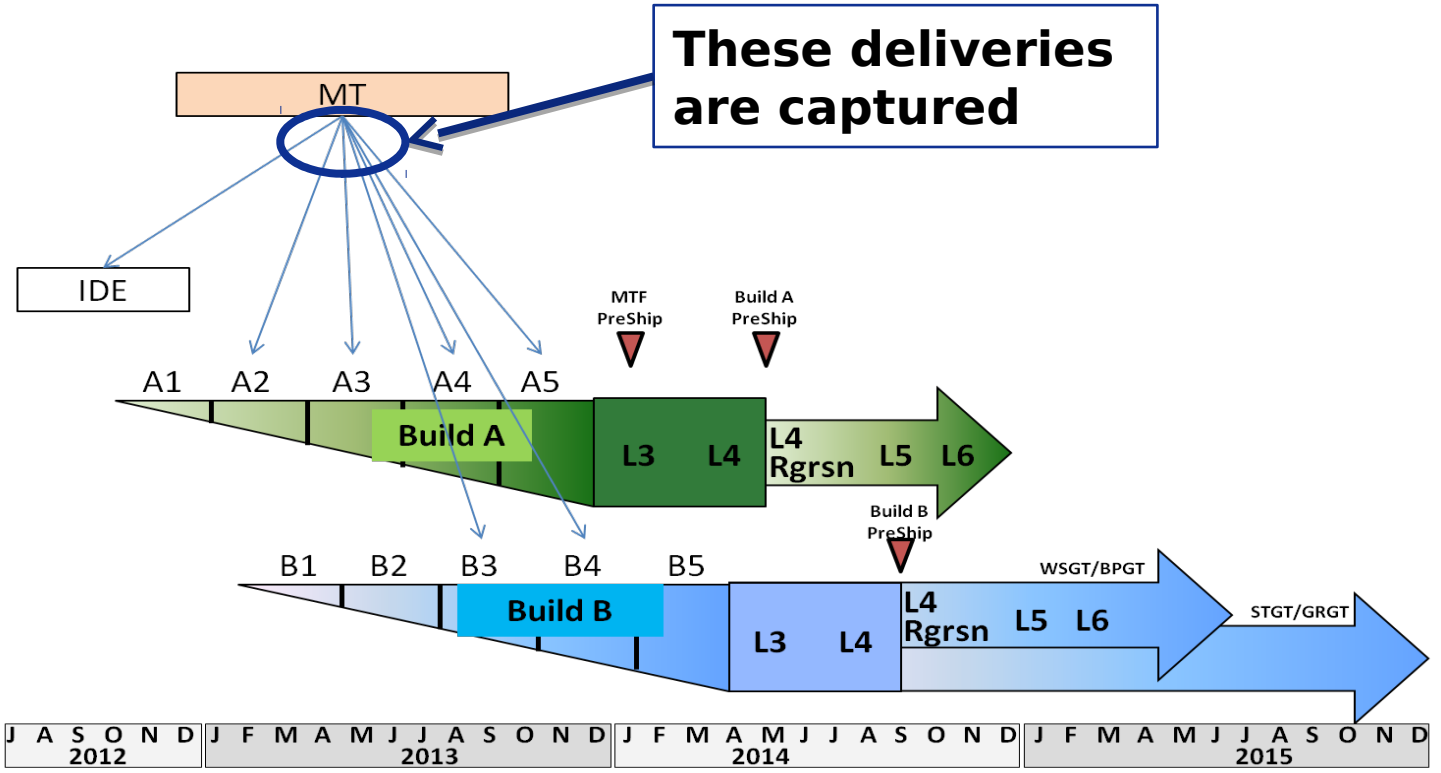
	Partitioning Code	MatchKeyID	PWBS	Task Name	Duration	Start	Finish
1	LINKS	0		SGSS Master IMS - LINKS	1326 d	Fri 9/3/10	Thu 12/31/15
2	LINKS	0	9	SGSS - LINKS	1326 d	Fri 9/3/10	Thu 12/31/15
350	MGMT	0		SGSS Master IMS - MGMT	1454 d	Mon 6/21/10	Fri 4/15/16
351	MGMT	0	9.01	SGSS - MGMT	1454 d	Mon 6/21/10	Fri 4/15/16
895	SEIT	0		SGSS Master IMS - SEIT	1315 d	Fri 9/3/10	Wed 12/9/15
896	SEIT	0	9.02	SGSS - SEIT	1315 d	Fri 9/3/10	Wed 12/9/15
2708	IAD	0		SGSS Master IMS - IAD	1368 d	Mon 6/21/10	Wed 12/9/15
2709	IAD	0	9.02	SGSS - IAD	1368 d	Mon 6/21/10	Wed 12/9/15
3165	ELEM	0		SGSS Master IMS - ELEM	1315 d	Fri 9/3/10	Wed 12/9/15
3166	ELEM	0	9.03	SGSS - ELEM	1315 d	Fri 9/3/10	Wed 12/9/15
3167	ELEM	0	9.03.01	Program Milestones	1315 d	Fri 9/3/10	Wed 12/9/15
3192	ELEM	0	9.03.01	Element Design Management	1205 d	Fri 9/3/10	Thu 7/2/15
3507	ELEM	0	9.03.02	(SGL) Timing & Frequency Hardware (NMSU)	460 d	Mon 5/23/11	Tue 3/26/13
3576	ELEM	0	9.03.05	(FGM) Fleet and Ground Management	1181 d	Fri 9/3/10	Fri 5/29/15
4674	ELEM	0	9.03.07	(SM) Service Management	1069 d	Fri 9/3/10	Mon 12/15/14
5875	EI	0		SGSS Master IMS - EI	1315 d	Fri 9/3/10	Wed 12/9/15
5876	EI	0	9.03	SGSS - EI	1315 d	Fri 9/3/10	Wed 12/9/15
7202	MTF	0		SGSS Master IMS - MTF	1247 d	Fri 9/3/10	Wed 9/2/15
7203	MTF	0	9.03	SGSS - MTF	1247 d	Fri 9/3/10	Wed 9/2/15
7960	DSP	0		SGSS Master IMS - DSP	1315 d	Fri 9/3/10	Wed 12/9/15
7961	DSP	0	9.03	SGSS - DSP	1315 d	Fri 9/3/10	Wed 12/9/15
9159	DEPLOY	0		SGSS Master IMS - DEPLOY	1326 d	Fri 9/3/10	Thu 12/31/15
9160	DEPLOY	0	9.03 & 9.06 & 9.08	SGSS - DEPLOY	1326 d	Fri 9/3/10	Thu 12/31/15
11637	HARRIS	0		SGSS Master IMS - HARRIS	1315 d	Fri 9/3/10	Wed 12/9/15

SGSS Analysis Schedule

- **Analysis schedule captures major workflows of design, development, I&T, and D&T**
  - **Design**, by element, from Element PDR thru Element CDR.
  - **Development**, by Subsystem/CI, from Element CDR thru L1/L2 testing and delivery to System I&T.
  - **Integration and test**, by Build/Increment, from L3 integration thru PreShip Reviews.
  - **Deployment & Transition**, by Build and by Site, including pre-shipment SN Site Facilitization activities.
- **Designed to allow traceability to IMS**
  - Maps back to IMS via Matchkey IDs
  - Logic based on corresponding IMS logic
- **Designed with future schedule expansion trade option in mind**
  - Higher resolution in D&T and I&T provide more moving pieces that can be adjusted as necessary
- **Basis for mapping costs and risks**
  - Analysis schedule can be refined based on level of detail for costs and risks

Design and Development Phase

- **Design organized by element**
  - Design through ePDR - Detailed design through eCDR
- **Development by element is defined to start at eCDR and continues until its final components are ready for level 3 I&T**
  - Component deliveries grouped by build and increment
  - Seven Components(EI, FGM, SGL, SM, DSP, MT, and USG) exist



Design and Development in Analysis Schedule

	Partitioning Code	MatchKeyID	Name	Duration	Start	Finish
3210	ELEM	0	Element Design Management	1281 d	Fri 9/3/10	Tue 10/20/15
4020	ELEM	0	(SGL) Timing & Frequency Hardware (NMSU)	460 d	Mon 5/23/11	Tue 3/26/13
4089	ELEM	0	(FGM) Fleet and Ground Management	1181 d	Fri 9/3/10	Fri 5/29/15
5226	ELEM	0	(EI) Enterprise Infrastructure	1161 d	Mon 10/4/10	Fri 5/29/15
5227	ELEM	0	EI - Major Reviews	385 d	Tue 3/20/12	Mon 9/30/13
5233	ELEM	0	EI - Givers/Receivers	650 d	Mon 2/28/11	Mon 9/30/13
5249	ELEM	0	EI - Element Leadership	932 d	Mon 10/4/10	Fri 6/27/14
5267	ELEM	0	EI - Material	1040 d	Mon 4/4/11	Fri 5/29/15
5351	ELEM	0	EI - Element Engineering	1056 d	Mon 10/4/10	Wed 12/24/14
5623	ELEM	0	EI - Develop Element Subsystems	747 d	Mon 10/4/10	Mon 9/30/13
5624	ELEM	0	Develop System Services Subsystem	490 d	Mon 7/18/11	Mon 7/1/13
5700	ELEM	0	Develop Core Framework Subsystem	747 d	Mon 10/4/10	Mon 9/30/13
5770	ELEM	0	Develop High Availability Operating Environment (HA OE) Support Subsystem	226 d	Mon 7/18/11	Mon 6/11/12
5803	ELEM	0	Develop High Availability Operating Environment (HA OE) Subsystem	553 d	Mon 7/18/11	Mon 9/30/13
5911	ELEM	0	Develop Preliminary Design for Network Topology	268 d	Mon 11/29/10	Fri 12/23/11
5920	ELEM	0	Develop M&C Network Subsystem	533 d	Mon 7/18/11	Fri 8/30/13
6039	ELEM	0	Develop TTC Network Subsystem	532 d	Mon 7/18/11	Thu 8/29/13
6166	ELEM	0	Develop Infrastructure Services Subsystem	513 d	Sun 8/14/11	Fri 8/30/13
6167	ELEM	0	Perform COTS Selection for Identity Mgmt - IDE (Inc 1)	175 d	Sun 8/14/11	Thu 4/26/12
6176	ELEM	0	Perform COTS Selection for Network Services - IDE (Inc 1)	48 d	Mon 2/27/12	Wed 5/2/12
6181	ELEM	0	Perform COTS Selection for Privilege Mgmt - Bld A (Inc 2)	266 d	Sun 8/14/11	Wed 8/8/12
6190	ELEM	0	Perform COTS Selection for Pre-PEP SW - Bld A (Inc 3)	110 d	Mon 6/25/12	Thu 11/29/12
6195	ELEM	0	Perform COTS Selection for Pre-PEP HW - Bld A (Inc 3)	110 d	Mon 6/25/12	Thu 11/29/12
6200	ELEM	0	Perform COTS Selection for PKI - Bld A (Inc 3)	110 d	Mon 6/25/12	Thu 11/29/12
6205	ELEM	0	Perform COTS Selection for XML Gateway - Bld A (Inc 3)	110 d	Mon 6/25/12	Thu 11/29/12
6210	ELEM	0	Develop SW for CTM - Bld A (Inc 3)	229 d	Mon 1/9/12	Thu 11/29/12
6226	ELEM	0	Perform COTS Selection for Host Intrusion Detection - Bld A (Inc 5)	110 d	Thu 1/3/13	Thu 6/6/13
6231	ELEM	0	Integrate Infrastructure Services Subsystem (L2)	382 d	Mon 2/27/12	Fri 8/30/13
6232	ELEM	0	Integrate Infrastructure Services Subsystem for IDE (Inc 1)	88 d	Mon 2/27/12	Thu 6/28/12
6239	ELEM	0	Integrate Infrastructure Services Subsystem for Bld A (Inc 2)	135 d	Mon 5/21/12	Fri 11/30/12
6240	ELEM	18461	Develop Test Plan for Infrastructure Services - Bld A (Inc 2)	40 d	Mon 5/21/12	Tue 7/17/12
6241	ELEM	18462	Develop Test Procedures for Infrastructure Services - Bld A (Inc 2)	30 d	Wed 7/18/12	Tue 8/28/12
6242	ELEM	18463	Perform L1 & L2 Component Integration for Infrastructure Services - Bld A (Inc 2)	20 d	Thu 9/6/12	Wed 10/3/12
6243	ELEM	18464	Perform L2 Subsystem Verification for Infrastructure Services - Bld A (Inc 2)	20 d	Thu 10/4/12	Wed 10/31/12
6244	ELEM	18465	Generate Test Report for Infrastructure Services - Bld A (Inc 2)	20 d	Thu 11/1/12	Fri 11/30/12
6245	ELEM	18466	Infrastructure Services Subsystem Available for L3 Integration - Bld A (Inc 2)			

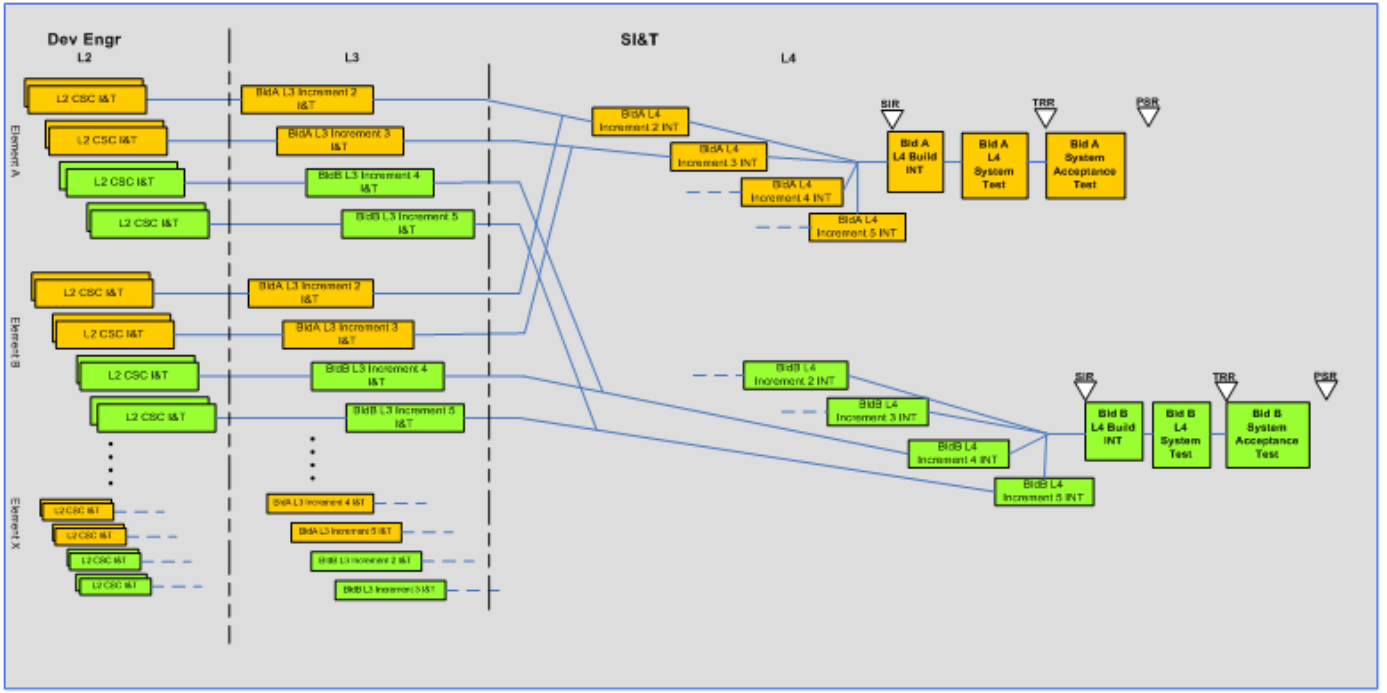
The last row shows where the IMS finally captures *one* EI component of build A, increment 2 being sent to Level 3 I&T

The analysis schedule captures the development of all EI build A, increment 2 components

	Task Name	Duration	Start	Finish
1	**Program Milestones**	**1361 days**	**Fri 9/3/10**	**Fri 11/20/15**
23	**Element Design**	**651 days**	**Fri 9/3/10**	**Fri 3/1/13**
42	**Element Development**	**347 days**	**Wed 9/5/12**	**Thu 1/2/14**
43	**Enterprise Infrastructure (EI)**	**279 days**	**Wed 9/5/12**	**Mon 9/30/13**
44	EI A2 Components	63 days	Wed 9/5/12	Fri 11/30/12
45	EI A3 Components	128 days	Wed 9/5/12	Fri 3/1/13
46	EI A4 Components	193 days	Wed 9/5/12	Fri 5/31/13
47	EI A5 Components	258 days	Wed 9/5/12	Fri 8/30/13
48	EI B3 Components	214 days	Wed 9/5/12	Mon 7/1/13
49	EI B4 Components	279 days	Wed 9/5/12	Mon 9/30/13

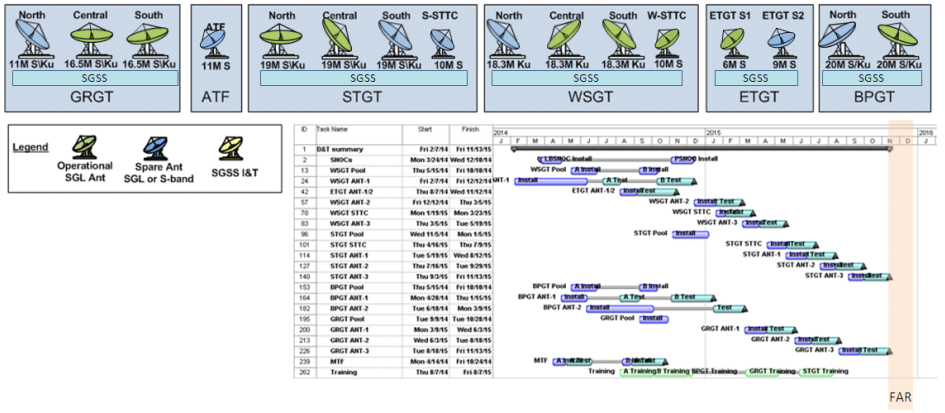
Integration and Test Phase

- **Level 3 integration and test occurs for the different increments as components arrive from elements**
- **Level 4 begins with SIR and runs through SAT**
- **Two semi-parallel paths for both builds**
- **After SAT, build A and build B go to D&T via the pre-ship and shipment activities**
- **MTF pre-ship and ship activities triggered during level 4 testing activities**

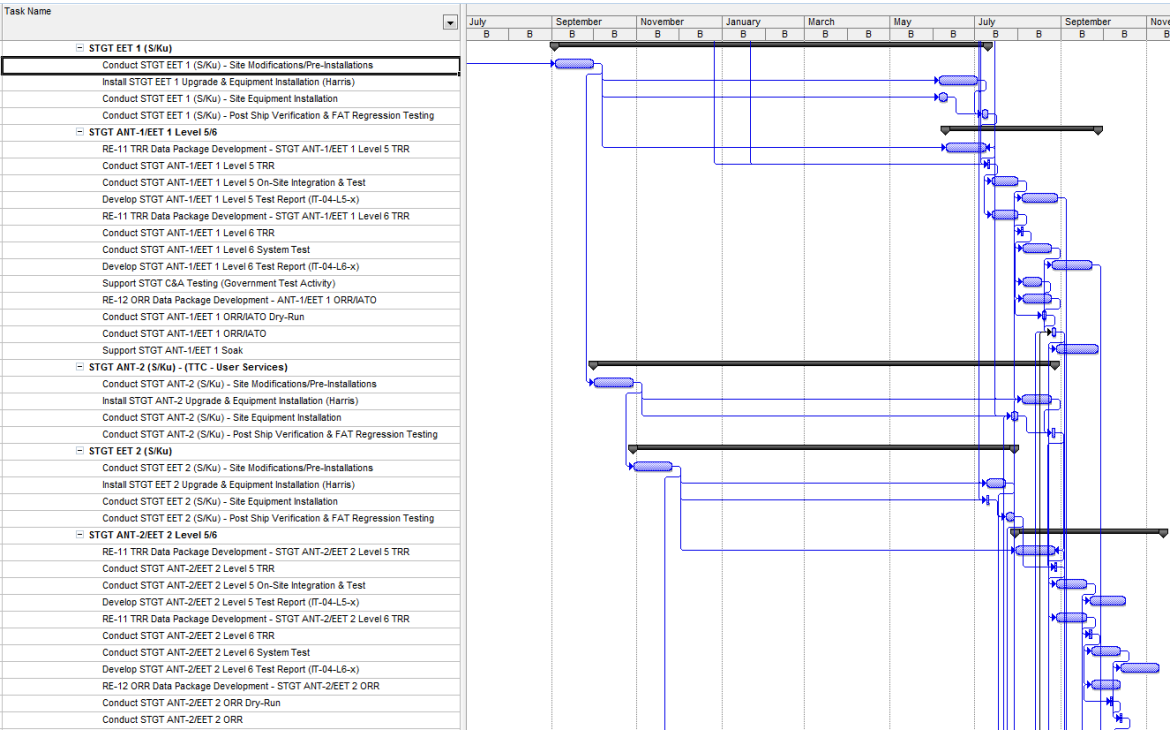


Deployment and Transition Phase

- **Facilitization activities for each site**
  - Site design and facilitization activities separated by a block of time in the IMS using constraints
  - That block of time is believed to represent project-specific activities that will need to be completed before facilitization
- **End points of D&T are the antenna ORRs**
  - FAR occurs after level 6 test documentation complete after final ORR
- **Lots of logical interaction between antennas**
  - In several cases, a portion of work on one antenna is the predecessor to beginningwork on another

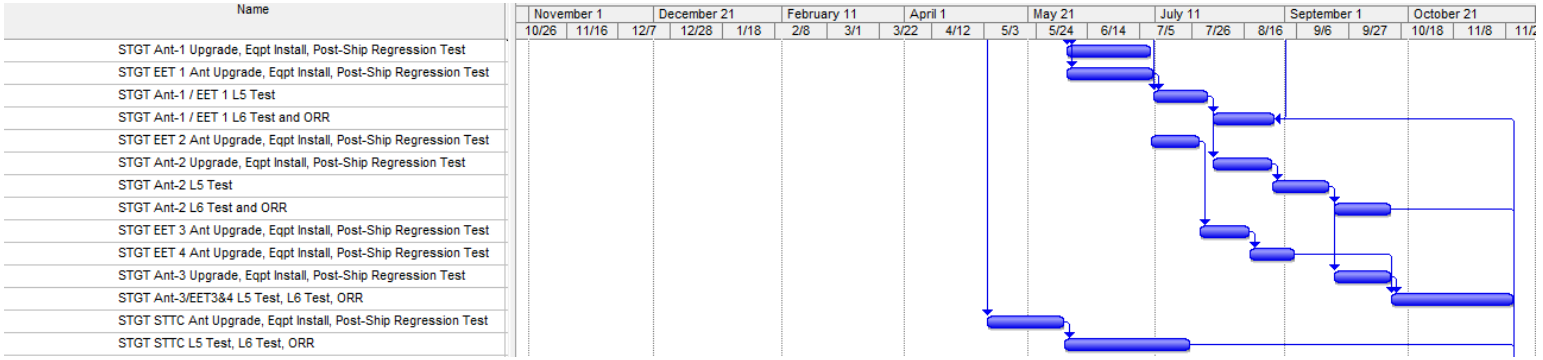


Deployment and Transition in Analysis Schedule



Simplification: IMS image (left) only shows two STGT antennas

Analysis Schedule (below) shows all three main antennas and STTC



Conclusions

- **Creation of an analysis schedule is a critical step in the JCL process**
  - The unique aspects of joint cost and schedule analysis result from attaching TD costs to activities, making the analysis schedule the backbone of the analysis
- **The JCL model is a model of reality, and the analysis schedule is therefore a model of the "real" schedule – which the IMS itself is not a perfect representation of**
  - Rote summarization of an IMS may be appropriate in some circumstances, but in general the IMS is one data source of many
  - In a conflict between a program's understanding of the work flow and the IMS, the model should reflect the human understanding of reality (though the conflict is a fundamental issue that should be resolved)

Thank You